THE SOCIAL PRACTICE OF TECHNICAL REVIEWS

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This paper presents initial findings from an ongoing research project studying the social and organizational practices of technical reviews at NASA. Technical reviews are a ubiquitous part of organizational life in most technical organizations, and one of the most consequential in terms of risk and innovation management. At NASA, a series of formal technical reviews are conducted across the mission lifecycle, including preliminary and critical design reviews in conceptual design as well as launch and flight readiness reviews in mission operations. Additionally, less formal engineering peer reviews are often conducted as pre-cursors to formal reviews. While recent reports at NASA–most prominent the Columbia investigation report–criticize the inadequate practice of technical reviews, little is known about the specific behavioral impacts of review processes. The objective of this research project is to systematically collect much needed empirical data to model the functional and dysfunctional effects of formal and informal technical reviews on work practices, managerial decision making, and organizational culture. We introduce a novel conceptual framework distinguishing formal, documentary reviews and informal, discursive reviews as two substantially different sets of practices. We show how each of these practices inhibit or facilitate effective knowledge sharing between project engineers and external experts. The paper also presents some initial empirical findings supporting this framework.

INTRODUCTION

Technical reviews are a ubiquitous part of organizational life in most technical organizations, and one of the most consequential in terms of risk and innovation management (Bell, Newman & Repenning, 2002). In industry, formal reviews are often used to support management decisions at phase gates, breaking up the over-arching product development processes into distinct “phases” (Clark & Fujimoto, 1991; Wheelwright & Clark, 1992), and informal engineering peer reviews are often conducted as pre-cursors to formal reviews. At NASA, a series of formal technical reviews are conducted across the mission lifecycle, including preliminary and critical design reviews in conceptual design as well as launch and flight readiness reviews in mission operations (Wertz & Larson, 1999; NASA, 2002).

In most organizations reviews are designed to fulfill a multitude of purposes: reviews produce assessments which inform managerial decisions about continuation, modification or termination of a project; reviews “offer an opportunity to add value to the products and to the sharing of knowledge by inviting outside experts”; and reviews are a “tool for communication” among different contractors and stakeholders (NASA, 2002). However, from a behavioral perspective the various goals are inherently contradictory, and can create dysfunctional practices. In particular, there is a significant tension between knowledge sharing and project assessment. When assessments are conducted in order to hold individuals and groups accountable for success and failure, employees may begin to look out for themselves and “game” the system rather than focusing on common goals of knowledge sharing and risk mitigation.

Recent studies at NASA criticize the inadequate practice of formal reviews (NASA, 2000). The Columbia accident investigation provides the most recent critique (NASA, 2003), and analyses of the Challenger Flight Readiness Review found that "conformity enforced by fear was a key factor in rendering the decision process dysfunctional" (Feldman, 2000). Some analyses of accidents provide specific examples where reviews could have mitigated risks (Vaughan, 1996), and other analyses have estimated that around 80% of post-launch problems/failures "possibly could have been identified in the design review" (Quinn, 1994).

These studies identify the topic of technical design reviews as an important and novel research agenda. The task now is to more thoroughly explore the social practice of reviews including their effects, by studying them in situ – in the organizational context in which they take place. Our paper addresses this research space by establishing a conceptual framework that distinguishes documentary and discursive review practices, and presents an empirical study on the current social and organizational practices of technical reviews at NASA, identifying both functional and dysfunctional effects and their implications for knowledge sharing and risk mitigation.

CONCEPTUAL FRAMEWORK

Reviews Reconsidered as a Social Practice

Reviews do not take place in isolation. Reviews are situated human practices shaped by the organizational rules and structures they are embedded in. Review practices in turn play an active part in creating and reproducing the very organizational structures they draw upon. This dynamic interplay between situated activities and governing rules

and structures has been called “structuration” (Giddens, 1984). A comprehensive social theory of reviews has to take this dynamic between activities and structures into account.

Reviews are structured to serve as “highly consequential moments of organizational accountability” (Bell, Newman & Repenning, 2002), and the social practice of accounting from general management theory provides a starting point for understanding the social practice of technical reviews. In the 1980’s, critical research began to study accounting "as a social and institutional practice, one that is intrinsic to, and constitutive of social relations, rather than derivative or secondary" (Miller, 1994). More recently, research has moved beyond a focus on formal assessment practices where specific forms of interactions are codified in legal or organizational rules and guidelines, and have also addressed on informal assessment practices (Jordan & Putz, 2003).

The present study applies and further develops a social practice framework of assessments recently introduced be Jordan and Putz (2003), which establishes a three-part typology that distinguishes two kinds of informal assessments – inherent and discursive assessments – from formal, documentary assessments. The framework further shows, how an over-reliance on documentary assessment can lead to far-reaching dysfunctional effects on work practices, on corporate decision-making and on the structure and culture of organizations.

A Social Practice Framework of Assessments

Inherent assessments are a chronic feature of all human conduct in the ongoing flow of activities. They occur routinely, effortlessly and unavoidably as part of any non-solitary human activity where people rely on a shared sense of purpose. All of us make

assessments of each other all the time, assuming that we each can or can not, will or will not, do certain sorts of things. Inherent assessments are not usually made explicit in the form of verbal utterances or mental descriptions but tend to remain in the sphere of practical consciousness. They are made in the interest of the individual attempting to align (or misalign) with the group. As such they constitute one of the fundamental mechanisms by which learning occurs. A baby or toddler continuously assesses approval or disapproval of its actions by family members. Newcomers adjust their talk and nonverbal interactions to those of a workgroup they are entering. Neophytes become full members of communities of practice by quickly and unobtrusively monitoring responses and reactions of other members (and thereby gaining access to the group norms they need and want to adopt). Inherent assessments occur spontaneously because they fulfill a necessary function in people's coordination with each other. Though tacit and implicit, inherent assessments are absolutely crucial for smooth, interpersonal interaction and for carrying out the work of a community of practice or any other social formation.

A discursive assessment happens, when participants find a reason to make the unspoken, inherent assessment explicit. Discursive assessments -- like inherent assessments -- are generated within the group to figure out, collaboratively, what state the group is in and what to do about that. The difference is that while inherent assessments rely on individual nonverbal monitoring and result in individual behavioral adjustment, discursive assessments make issues public by putting them into words, i.e. including them to the group discourse. Discursive assessments are socially mobile. They can be referred to, doubted, agreed with, or revised by people who are part of the group. They have become "social objects". Unlike inherent assessments, they have persistence. People

can point to them at a later time; they can be passed around, discussed, and modified. However, it is important to note, that these kinds of assessments remain the property of the group, used by its members individually and collectively to advance the group's enterprise. They create a shared understanding of individual roles and responsibilities and thereby work out a division of labor. They allow on the job learning and the sharing of tacit and explicit knowledge among peers and other directly involved parties.

Documentary assessments are the formal type of evaluations we are all most familiar with. They involve externally mandated, stable symbolic representations in the form of tests, surveys, checklists, plans, targets and similar instruments. Documentary assessments occur when an enduring record of some kind is produced, a set of marks on a piece of paper (or on a computer). Here we see an extension of the mobility of the assessment beyond the group. Formal assessments of this sort have the properties of "immutable mobiles" (Latour, 1986), that is to say, once constructed, the content becomes fixed while the assessment itself becomes mobile as a document. While discursive assessments move within the group that spawned them, documentary assessments can exist independent of the situation in which they were generated. They become public documents that can move within a larger socio-economic system. Form a local vantage point, in most cases, documentary assessments are imposed from the outside, carried out in the interest of some superordinate group, generally to further interests that do not directly overlap with those of the group being assessed

The translation of real-word phenomena – work processes and results – into a predefined language of requirements and measurements unavoidably involves the loss of contextual information. Whoever receives this information is left ignorant about the why

or how, and what this could mean for getting the work done. On the positive side, stripping away the context allows for data consistency and expanded distribution. The enormous potency of documentary assessments for the coordination and control of organizations is based on this ability to gather consistent, thus comparable, data from distant subunits to any place where decisions are made. It is the intention to move assessments from the hands of interested parties to some sort of formal, objective procedure. Documentary assessments draw on instruments that are insensitive to differences in ethnicity, gender, social status, work and learning environment, personal histories and relationships, and all other potential sources of bias.

The strengths of documentary assessments are at the same time their weaknesses. The stripping of context information in combination with the extended distribution of immutable documents makes it possible that various distant constituencies appropriate the assessments to further their own interest. Documentary assessments are necessarily open to interpretation and allows for uses that are not foreseeable by those who first produce the assessments. Therefore workers often suspect that management might draw on these kinds of data to justify decisions about resource allocation, plant closings and the fate of projects and individual workers. When performance data get used to punish and reward, a strong motivation is generated to manipulate the numbers. The game becomes one of making the numbers look good rather than improving the learning or work process. The fact that documentary assessments are carried out in the interest of external constituencies has effects on the way data are produced, work practices are changed and relationships of collaboration, openness and trust are affected. It is this fragile balance between unintended dysfunctional impacts and the beneficial features of

documentary assessments that makes them such a tricky yet consequential means in the effort to coordinate organizations.

While the social practice framework above was originally developed to characterize a broad variety of formal and informal judgments, evaluations, measurements and metrics in educational and business settings (Jordan & Putz, 2003), the present paper specifically focuses on technical reviews, and utilizes an adapted and modified typology of discursive and documentary reviews with their respective functional and dysfunctional effects.

INITIAL FINDINGS

Documentary Review Practices

> *"Okay, for reviews we had 8.2 kg of documents, we employed 117 reviewers so far, we had 14 reviews, the cost of reviewers were $208,000, they reviewed 528 items of ISO compliance elements, we complied with 221 design principles and we had 21 versions of the requirements documents based on different reviewers, and we produced 1325 charts for different reviews." NASA Project Manager, 2003*

The very nature of documentary assessment is the production of written accounts, with stable records produced for external distribution, and some project managers are very aware of functional and dysfunctional effects of documentary reviews. Dysfunctional

effects include flawed data which persists, euphemistic language that obfuscates reality, changing work practices, and changes to organizational culture.

A project manager describes that reviews conducted in the early design phases of a project are prone to the presentation of flawed data and false estimations: "... people tend to put down on viewgraphs things that are just simply untrue because they are based on early wrong assumptions." This problem is a very serious one, since false numbers presented and documented in early reviews do not get corrected later on, even against the better knowledge of engineers involved. Additionally, undesired facts can become hidden through the use of euphemistic language. "And there's also the agency's stigma on, you know, I had a failure, I had a problem and I have to talk about it. Well, how come you didn't catch it? So people tend to use very euphemistic language."

Changes in how work is actually carried out often occur as people adjust to the assessment procedures. While intended to increase productivity and quality in education and business, what often occurs is the opposite. Employees tend to make their work look good in compliance with the established and highly visible requirements sacrificing other objects and long-term goals. These adaptations often make the process as a whole more cumbersome and more expensive.

"I found a lot of problems with the current review system, okay? Number one is the fact that people ask to have reviews very early. And what it does is because there is a whole series of reviews and the idea is: oh yeah, we have to have reviews from the beginnings, so they don't go in the wrong direction, okay? Unfortunately what it does is that engineers have a tendency to produce view-graphs with some thoughts they do have

very early. And then these view-graphs, because something is in writing and it's on the viewgraph and it's been reviewed, somehow it gets some notoriety. Well, it may be based on completely unrealistic assumptions. Especially I have a beef with early cost estimates. Because you know, if I ask you to build this table, how much you gonna spend, okay? And you don't have the time to figure out if it Formica or if it's plywood and you didn't have time ask me enough questions what I am gonna use it for and if you can carry it through the doors, how wide it is. But on the viewgraph you put 327 dollars. And the problem I notice with these early reviews is that, you know, this become 327 dollars and carries this 327 dollar for a long time and it will never become 2000 dollars because then you feel like, oh, you didn't know what you were talking about and why there is this big change, even though it's actually a better number, right? And I think that a lot of cost problems that we encounter is due to this early, you know, on one hand they think it's good to do it early, but I think there's also a problem with this approach. You do it early and then you never double or triple that amount because you look stupid or incompetent."

"We usually spend a whole day describing things and there's different people from different subsystems presenting things and people are just tired and it takes a long time and there's the chairman of the board and it says, come on, next, we are 37 minutes late, come on, we gotta get going, okay? For example I had an experiment were this new technology was an inflatable antenna, okay? And so we kept on reviewing the inflatable part, the mylar, the deployment mechanism, all of these things. We ended up at the last minute, working out 600k additional for a box. Because the box was misdesigned. Well the box was in every review, but here the result is new stuff. And the guy would come out and it was just one guy, and he'd say I did find aluminum -- yeah, good, good -- and I

calculated a lots -- good, good -- nobody wanted to pay attention to this and spend the time and nobody final reviewed it. And there was only one engineer in the company and he ended up making mistakes. Nobody has ever reviewed this even though we had all these NASA reviews."

The first of these two statements might be considered as an instance of “fixing the numbers”. But there is more to it. In the long run false cost estimations and too optimistic technical descriptions may lead to wrong resource allocation and to a suboptimal division of labor. If for example a subsystem is presented as unproblematic, straightforward solution while in reality in involves challenging questions, the subsystem might not get the financial and human resources necessary. And that is exactly what happened in the second example.

More subtle, however, may be changes that occur in the culture of work. When evaluation data gain high visibility within a larger organization, new levels of accountability emerge. When reputation and perceived competency is at stake employees look out for themselves to avoid recrimination rather than focusing on shared goals. There arises a temptation to focus on short-term success, and to deny responsibility for failure. As a consequence one may see mistrust, competitiveness, passing-the-buck behavior, and what is known in the workplace as a “cover-your-ass” attitude. Some organizational theorists (e.g. Gittell, 2000) have argued that quantitative performance measurements inevitably generate some level of dysfunctional behavior since they tend to operate with a relatively low level of trust.

As mentioned above, Feldman (Feldman, 2000) has shown that the NASA Marshall Center Board Flight Readiness Review for the Challenger Space Shuttle

enforced conformity by fear. Here are two statements from different project managers at NASA illustrate how formal reviews can yield a defensive and restrictive culture: "Reviews are actually a game. They are high stakes. The goal of the project manager is to get through the review as much as it is to root out problems."

"So I am saying a lot of the times if you look at the reviews you look what's on the agenda, who is involved, you know what's their expertise, what's covered, time, how many charts – it's all right. But the psychology is all wrong. Because, you know, if I ask you, let's say: You know you guys been - you know management consensus - you guys been doing this for what: three months? You know, what have you accomplished? okay? well, you know, so I'm gonna get uh 5 more days and you'll make a presentation, we'll critique it. Well, that immediately sets up that two sides of a barricade, unfortunately. What you gonna be doing is: give me your presentation. And you in a sense, you know you work for a solid presentation. And you put all your thought and you effort into this and then you'll be sitting here, you know, checking it out, you know, leaning back in your chairs and you in a sense, you wanna look smart. You wanna prove that you have thought of everything. And we, we prove you wrong. Right. And that's I think is a bad psychology. Because that's the two sides prosecution and defense. And it's where we are not truly as a team looking at improving things."

Drawing attention to the problematic sides of documentary reviews is not to be misunderstood as an argument against the use of formal reviews per se. There is no doubt that formal reviews are necessary and beneficial. However, we need to significantly improve our knowledge about unintended, dysfunctional effects in order to establish a

more accurate understanding of their characteristics as social practices embedded in organizational structures and rules.

Discursive Review Practices

> *"Before I was a project manager I never liked reviews. And I vowed that if I'll become a project manager I'll completely do it differently. Because I don't like the psychology of the reviews. I think that it's, uh the way we conduct reviews, it's kind of like our judicial system. You know, where there is a prosecution and defense. It's not truly looking for the truth. It's kind of like, it's either one side is trying to defend itself and the other side is trying to zap on them." NASA Project Manager, 2003*

Some project managers are very aware of the strengths but also of limitations of documentary reviews. And therefore some of them developed their own way of conducting additional informal peer reviews which are at the core discursive assessments. One of their most salient features is that they avoid the production of written records. Rather they remain verbal communications among only a few subject matter experts. It is the project team or the local group of engineers responsible for a subsystem that is in control of the peer reviews. The following three statements vividly describe the substantial difference between documentary and discursive reviews. The first statement draws a clear connection between purely verbal group-endogenous evaluations and the avoidance of dysfunctional commitments to early and often wrong cost estimations. The second on highlights the open-ended nature of discursive reviews which allow in depth

knowledge-sharing and out-of-the-box-thinking. The third excerpt explains the importance of keeping the number of people involved small, once again in order to avoid the production of written records.

"So anyways, the bottom line is that what I decided to do, is do peer reviews and I'll have some comment to you doing peer reviews correctly. But the peer reviews I insist on getting these peer reviews from the very beginning. And the psychology I change. You know, we get together in a room and I go to the engineers in the room and we chat about it. I don't let people write anything down for a long time. I insist that they don't. They don't send me emails. We talk about it. We talk about it for a long time. And that's to prevent this 327 dollars kind of problem, right? And we talked about it and I am telling you tested this on different subsystems, just as a test. On subsystems where I asked people to write down the numbers, they evolved only maybe 30 percents. On subsystems where we only talked, they evolved up to 400 percent. You know I didn't do it for a 3000 elements, so it's not a statistical sample, but there is something in it."

"Okay, the difference to me is the formal review is when there is a chairman, there is a panel, and there are viewgraphs presented and there is a package and that has the objective of the reviews, success criteria for the review and at the end the panel convenes and decides will they successfully pass the review, if the objectives are met and what is the outcome of the review. That's formal. To me a peer review on the other hand is when we get together for all the subsystems, I've done this for subsystems. Were I say, okay we have two engineers that are experienced from previous missions and they talk to this engineer and no viewgraphs, he just looks into his files, pulls out stuff, they ask questions and then they maybe get together the next day discuss it more, it's two hours

and two hours the next day maybe. And they kind of start try getting an impression. There is in there anything that that person prepares for. So they can ask about different things."

"[Conducting reviews in a conference room] changes the psychology and you can not reach out for materials. So it has to be conducted in the office. And I noticed that if there's three or more peer reviewers then there is not enough dialog going on, because there is not enough time to ask questions and more. So just like here: I wanna show you what I have here. Well the two of you then see it, he saw it. You didn't see it because you know you have to pull in, you have to look at it, I have to show it to you, or I have to have four copies. If I make copies I better put you know a more formal material. You see where we are going? Now, if only the two of you are here, I can show it to you and both of you can look at it and you know what's on it. So I think the best peer reviews are you know never more than three people. Never more then three people. The best things are two on two, one on two. That are the best interactions."

The next dialog points out how skeptical a project manager reacts to any kind of written documents or standardization even regarding the administrative matters of peer reviews. There are various reasons for that: the avoidance of externally available and consequential judgments on individuals is one, keeping responsibility and control for planning and execution of reviews local is another one.

"Project manager: Well, to tell you the truth, such a list will never be created. Because the you are putting judgment on people. Who is an expert who isn't an expert and who'd wanna make such a list? And the list will become outdated and people are not

available. So what you do is, you know you want an expert in avionics, you call the manager of that particular section. You have to just know.

Interviewer: So what do you think of having a more permanent sort of review office or people who are dedicated reviewers? Where we can know where to find them and we know what they are experts on

Project Manager: Well, I'll tell you - well, there is a process like [Review Process Manager] for example, you know he is a process owner for the reviews at JPL and there are people, who are in an office and we have project support people who can help you with costs, they are cost reviewers and you know, ISO reviewers and design principle reviewers, so there is that. And you use them. But, you can't let it become, you just go to the review office, because then there may be a tendency: okay, I'd been at the review office, and they'd sent some guys and they'd reviewed it. Instead of putting more thought into this: what do you really need out of the review? Do you need a rubber stamp? Do you need some smart people to share some general comments? Or what do you really think, can go wrong? And then you have to penetrate these things."

Informal discursive peer reviews are substantially different to formal reviews. However they are not mutually exclusive or competitive alternatives. If used with creativity these two kinds can be combined to improve the quality of formal reviews. Below a project manager describes how a system review can be enhanced by utilizing the results of peer reviews:

"[...] what I found is that this [system review] is the area where you have to have overlap between the peer groups. So the actual system review takes place in a formal review. This is I ask the leads of these different peer groups to come to the formal review

and then it's four hours not three days. Where everybody is really burned out and tired. And then we have peer group reports, just real reports, this is what the problem was with this subsystem and this is a problem with this subsystem and then everybody stays and participates in the discussion of the system. Because you have to got all the subsystems to discuss the system implications. So the system has peer group and also has a discussion at the formal review."

FURTHER RESEARCH

Methodologically this research is applying a multiple-case study design (Eisenhardt, 1989; Yin, 1984) which follows an inductive grounded theory approach (Glaser & Strauss, 1967). The strengths of building conceptual models from inductive case studies is the likelihood of generating novel theoretical constructs, that are relevant, empirically valid, and easily testable. The new theoretical model emerges as closely as possible to the systematically gathered empirical data. This research is combining multiple data collection methods such as interviews, document analysis, participatory observation and video analysis. This allows the triangulation of findings (Jick, 1979) and ultimately a stronger substantiation of the theoretical model (Eisenhardt, 1989).

SUMMARY AND CONCLUSIONS

Initial findings from in-depth interviews with project managers and document analyses show that formal documentary reviews can lead to undesired and dysfunctional consequences while informal discursive assessments facilitate in depth knowledge sharing and out-of the box thinking.

Undesired, dysfunctional effects of documentary reviews fall into three categories: a) inaccurate numbers and euphemistic language, b) changing work processes and resource allocation to the detriment of over-all project goals and c) establishing a restrictive culture, where interactions are framed as prosecution versus defense situation. The results indicate that dysfunctional effects are tightly connected to the very nature of documentary assessments: production of written, i.e. stable records, extended distribution, context stripping, openness for mis-interpretation and the fact that it is usually imposed from the outside.

Some project managers are very aware of the limitations of documentary reviews. Therefore some of them developed their own ways of conducting additional informal peer reviews which are at the core discursive assessments. One of their most salient features is the lack of written records which is deliberately avoided. Rather they are conducted as verbal communications among only a few subject matter experts. This setting avoids the above-mentioned dysfunctional effects of documentary reviews and allows for in depth knowledge sharing between project engineers and external experts. Discursive peer reviews facilitate the communication within communities of subject matter experts and allow individual project engineers to learn from more experienced colleagues.

The initial findings show that formal documentary reviews are prone to dysfunctional effects not seen with discursive reviews. If this holds true, NASA and other organizations need to reconsider their current management policies which focus almost exclusively on documentary assessments. In fact at NASA the recent accidents have even reinforced this tendency towards formal, documentary reviews. However,

these findings indicate that what is needed, is not more of the same but a balanced approach which combines documentary with discursive reviews in a smart and novel way.

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